

LIGO-E1300128-v3

aLIGO Interferometer Optics Positions and Orientations for Initial Alignment

■ Revision History

■ Version -v1

2/7/2013, D. Coyne: initial release to support update to the L1 PRC and BS alignment solutions

■ Version -v2

2/12/2013, D. Coyne

1) Fixed error in calculation to insure that the PR2, PR3, SR2, SR3 optics are oriented vertically with respect to the local gravity vector (i.e. in local coordinates). Previous calculation had a small pitch error (due to yaw rotation in the global coordinate frame instead of local frame).

2) completed calculations of the locations and orientations of all of the H1 PRC and SRC optics (was partial for -v1)

3) Made nicely formatted tables for the summary tables

(note the version of this notebook which is posted to the DCC under E1300128-v1 includes the changes noted above for -v2)

8/30/2013. D. Coyne

4) added notes on the distances between the PRC & SRC optics noted in T0900043-v11, and compared them to the distances calculated herein

- 5) Changed from Rotate3D (obsolete) to RotationTransform
 - 6) Changed from CrossProduct (obsolete) to Cross
 - 7) Added a comparison to the global coordinates reported by IO for the PRC & SRC in E1200616 (H1) and E1200274-v3 (L1)
- 9/6/2013 D. Coyne posted to DCC for discussion with commissioners regarding apparent error in SR3 optic positioning resulting in poor modal overlap with PRC cavity

■ Version -v3

9/6/2013, D. Coyne

- 1) Changed length/distance comparisons to T0900043-v11 from the cold case to the nominal design case for 12.5 W of PSL input power.
- 2) Changed the global positions of the H1 SRM and SR2 HR centers to be consistent with IO's (Luke William's) H1 master coordinate list E1200616-v7. The positions of these optics changed based on the as-built radii of curvature (ROC).
- 3) N.B. : According to the IO H1 Master Coordinates List, the center of the HR fface of PRM is at $\{-20193.8, -628.0, -94.2\}$, or 4.2 mm different in x compared to E1100494-v3! Leaving as is for now.

■ Notes and Notation

■ Summary

■ Optic Parameters

(Debug) In[254]:=

```

opticLabel = {"PRM HR", "PR2 HR", "PR3 HR",
               "BS HR", "BS ARs", "SRM HR", "SR2 HR",
               "SR3 HR", "CPx", "ITMx", "CPy", "ITMy"};
nOptics = Length[opticLabel];
opticWedge =
  {"NA", "NA", "NA", wedgeBS, "NA", "NA", "NA",
   "NA", wedgeCPx, wedgeITMx, wedgeCPy, wedgeITMy};
opticThick = {"NA", "NA", "NA", BSThick, "NA", "NA", "NA",
               "NA", CPxThick, ITMxThick, CPyThick, ITMyThick};
opticDiameter = {"NA", "NA", "NA", BSDiameter,
                  "NA", "NA", "NA", "NA", CPxDiameter,
                  ITMxDiameter, CPyDiameter, ITMyDiameter};

```

(Debug) In[259]:=

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formattedTableParameters
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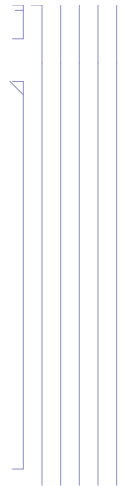
(Debug) Out[259]=

Optic	wedge		Thickness	Diameter
	rad	deg		
PRM HR	NA	NA	NA	NA
PR2 HR	NA	NA	NA	NA
PR3 HR	NA	NA	NA	NA
BS HR	0.001326	0.076000	60.410000	369.850000
BS ARs	NA	NA	NA	NA
SRM HR	NA	NA	NA	NA
SR2 HR	NA	NA	NA	NA
SR3 HR	NA	NA	NA	NA
CPx	0.001204	0.069000	99.820000	340.130000
ITMx	0.001344	0.077000	200.220000	340.130000
CPy	0.001204	0.069000	99.910000	340.220000
ITMy	0.001361	0.078000	199.640000	340.060000

■ Results

(Debug) In[260]:=

```
opticPositionG =  
  {p15, p14, p6, p5, p7, p17, p16, p8, p11, p9, p3, p1};  
opticPositionL = opticPositionG.Rhc;  
opticNormalG =  
  {n15, n14, n6, n5y, n13, n17, n16, n8, n11, n9, n3, n1};  
opticNormalL = opticNormalG.Rhc;  
opticYaw = {PRMyaw, PR2yaw, PR3yaw,  
  BSyaw, 0, SRMyaw, SR2yaw, SR3yaw, 0, 0, 0, 0};
```



(Debug) In[265]=

formattedTablePositions

(Debug) Out[265]=

Optic	Global Coordinates (mm)			Local Coordinates (mm)		
	Xg	Yg	Zg	Xl	Yl	Zl
PRM HR	-2018- 9.- 6	-628.0	-95.0	-2018- 9.- 7	-628.0	-82.5
PR2 HR	-3581- .3	-530.4	-84.8	-3581- .4	-530.4	-82.6
PR3 HR	-1974- 0.- 0	-173.9	-94.9	-1974- 0.- 1	-173.9	-82.7
BS HR	-202.6	-183.8	-83.0	-202.7	-183.8	-82.9
BS ARs	-183.9	-250.1	-83.0	-183.9	-250.1	-82.9
SRM HR	305.4	-1987- 5.- 8	-114.1	305.3	-1987- 5.- 8	-114.5
SR2 HR	-594.1	-4161- .5	-105.0	-594.2	-4161- .5	-104.7
SR3 HR	-174.1	-1961- 5.- 9	-94.9	-174.2	-1961- 5.- 9	-95.0
CPx	4792.9	-200.0	-80.0	4792.9	-200.0	-83.0
ITMx	5013.0	-200.0	-80.0	5012.9	-200.0	-83.1
CPy	-200.0	4763.7	-80.0	-200.0	4763.7	-79.8
ITMy	-200.0	4983.1	-80.0	-200.0	4983.1	-79.8

(Debug) In[266]=

formattedTableNormals

(Debug) Out[266]=

Optic	Normal Unit Vector (global) (mm)			Normal Unit Vector (local) (mm)		
	Ug	Vg	Wg	Ul	Vl	Wl

PRM HR	0.999- 98- 3	0.005- 87- 6	0.000- 61- 2	0.999- 98- 3	0.005- 87- 6	-0.00- 00- 07
PR2 HR	-0.99- 99- 67	0.008- 09- 2	-0.00- 06- 20	-0.99- 99- 67	0.008- 09- 2	-0.00- 00- 00
PR3 HR	0.999- 93- 6	-0.01- 12- 84	0.000- 62- 0	0.999- 93- 6	-0.01- 12- 84	0.000- 00- 0
BS HR	-0.70- 67- 36	0.707- 47- 8	0.000- 00- 0	-0.70- 67- 36	0.707- 47- 8	0.000- 44- 7
BS ARs	0.705- 79- 7	-0.70- 84- 15	0.000- 00- 0	0.705- 79- 6	-0.70- 84- 15	-0.00- 04- 46
SRM HR	-0.05- 71- 47	0.998- 36- 6	0.000- 57- 7	-0.05- 71- 47	0.998- 36- 6	0.000- 62- 5
SR2 HR	0.042- 16- 1	-0.99- 91- 11	0.000- 03- 9	0.042- 16- 1	-0.99- 91- 11	0.000- 00- 0
SR3 HR	-0.01- 38- 36	0.999- 90- 4	-0.00- 00- 21	-0.01- 38- 36	0.999- 90- 4	-0.00- 00- 00
CPx	0.999- 99- 9	0.000- 00- 0	-0.00- 13- 44	0.999- 99- 8	0.000- 00- 0	-0.00- 19- 63
ITMx	1.000- 00- 0	0.000- 00- 0	0.000- 00- 0	1.000- 00- 0	0.000- 00- 0	-0.00- 06- 19
CPy	0.000- 00- 0	0.999- 99- 9	-0.00- 13- 61	-0.00- 00- 01	0.999- 99- 9	-0.00- 13- 49
ITMy	0.000- 00- 0	1.000- 00- 0	0.000- 00- 0	0.000- 00- 0	1.000- 00- 0	0.000- 01- 2

(Debug) In[267]:=

formattedTableAngles

(Debug) Out[267]=

Optic	Yaw			
	rad	deg	min	sec
PRM HR	-0.005877	0.	-20.	-12.
PR2 HR	0.008092	0.	27.	49.
PR3 HR	-0.011284	0.	-38.	-47.
BS HR	-0.784873	-44.	-58.	-12.
BS ARs	0.000000	0.	0.	0.
SRM HR	-0.057178	-3.	-16.	-34.
SR2 HR	-0.042173	-2.	-24.	-59.
SR3 HR	0.013836	0.	47.	34.
CPx	0.000000	0.	0.	0.
ITMx	0.000000	0.	0.	0.
CPy	0.000000	0.	0.	0.
ITMy	0.000000	0.	0.	0.

■ Zemax results

Zemax results are from D0901920-v13

The wedge angle magnitudes (but not orientations/signs) reported in the Zemax optical layout, D0901920-v13 differ, as follows:

ITMx = ITM10? = 0.077 deg (same value but serial number designation is wrong)

ITMy = ITM11? = 0.076 deg (value and serial number incorrect)

CPx = CP01 = 0.070 deg (serial number correct, used “final” wedge angle instead of C1107164-v1 value)

CPy = CP02 = 0.069 deg (serial number is incorrect)

BS = BS06 = 0.076 deg (same)

(Debug) In[268]:=

```

opticLabelZemax = {"PRM HR", "PR2 HR",
  "PR3 HR", "BS HR", "BS ARs", "SRM HR", "SR2 HR",
  "SR3 HR", "ITMx", "ITMy", "ETMx", "ETMy"};
nOpticsZemax = Length[opticLabelZemax];
opticPosGZemax = {{-20194.3, -628.0, -95.8},
  {-3581.7, -530.4, -84.5}, {-19740.5, -174.0, -94.8},
  {-202.6, -183.9, -82.9}, {-184.0, -249.8, -82.9},
  {305.4, -19908.6, -113.2}, {-594.1, -4178.1, -104.4},
  {-174.2, -19615.9, -94.5}, {5013.0, -200.0, -80.0},
  {-200.0, 4983.1, -80.0}, {3999498.0, -200.0, -80.0},
  {-200.0, 3999468.1, -80.0}};

```

(Debug) In[271]:=

```

compareOpticLabel = opticLabelZemax[[1 ;; 10]];
nCompareOptics = 10;
comparePositionG = Drop[opticPositionG, {9, 11, 2}] -
  opticPosGZemax[[1 ;; 10]];

```

(Debug) In[274]:=

```

formattedTableComparePositions

```

(Debug) Out[274]=

Optic	Global Coordinate Difference (mm)		
	DXg	DYg	DZg
PRM HR	4.7	-0.0	0.8
PR2 HR	0.4	-0.0	-0.3
PR3 HR	0.5	0.1	-0.1
BS HR	-0.0	0.1	-0.1
BS ARs	0.1	-0.3	-0.1
SRM HR	-0.0	32.8	-0.9
SR2 HR	-0.0	16.6	-0.6
SR3 HR	0.1	0.0	-0.4
ITMx	0.0	0.0	0.0
ITMy	0.0	0.0	0.0

■ IO results

IO Layout results for PRM, PR2 and PR3 are from E1100494-v3, E1100495-v4:

```

opticLabelIO = {"PRM HR", "PR2 HR", "PR3 HR"};

```

```
nOpticsIO = Length[opticLabelIO];  
opticPosGIO = {{-20189.6, -628, -94.2}, {-3581.3, -530.4, -84.3}, {-19740, -177.4,  
-94.6}};
```

IO Layout results for PRM, PR2, PR3, SRM, SR2 and SR3 are from E1200616-v7 for H1 in global coordinates

(Debug) In[275]:=

```
opticLabelIO =  
  {"PRM HR", "PR2 HR", "PR3 HR", "BS HR", "BS ARs",  
   "SRM", "SR2", "SR3", "CPx", "ITMx", "CPy", "ITMy"};  
nOpticsIO = Length[opticLabelIO];  
opticPosGIO =  
  {{-20193.8, -628, -94.2}, {-3581.3, -530.4, -84.3},  
   {-19740, -177.4, -94.6}, {-201.9, -183.9, -82.9},  
   {-183.3, -249.8, -82.9}, {305.4, -19875.8, -114.1},  
   {-594.1, -4161.5, -105.0}, {-174.1, -19615.9, -94.9},  
   {4793.0, -200.0, -80.0}, {5013.0, -200.0, -80.0},  
   {-200.0, 4763.1, -80.0}, {-200.0, 4983.1, -80.0}};
```

(Debug) In[278]:=

```
compareOpticLabel = opticLabelIO;  
nCompareOptics = Length[compareOpticLabel];  
comparePositionG = opticPositionG - opticPosGIO;
```

(Debug) In[281]:=

formattedTableComparePositions

(Debug) Out[281]=

Optic	Global Coordinate Difference (mm)		
	DXg	DYg	DZg
PRM HR	4.2	-0.0	-0.8
PR2 HR	0.0	-0.0	-0.5
PR3 HR	0.0	3.5	-0.3
BS HR	-0.7	0.1	-0.1
BS ARs	-0.6	-0.3	-0.1
SRM	-0.0	-0.0	0.0
SR2	-0.0	0.0	0.0
SR3	-0.0	0.0	0.0
CPx	-0.1	0.0	-0.0
ITMx	0.0	0.0	0.0
CPy	0.0	0.6	-0.0
ITMy	0.0	0.0	0.0

■ RC Length Results

(Debug) In[282]:=

```

RClengthsLabel =
  {"PRM to PR2", "PR2 to PR3", "PR3 to BS", "BS to CPy",
   "PRC", "SRM to SR2", "SR2 to SR3", "SR3 to BS",
   "BS effective thickness", "BS to CPx", "SRC"};
nRClengths = Length[RClengthsLabel];
RClengthsIO = {dPRMtoPR2, dPR2toPR3,
  dPR3toBS, dBStoCPy, dPRCIO, dSRMtoSR2,
  dSR2toSR3, dSR3toBS, dBSe, dBStoCPx, dSRCIO};
RClengths = {d1415, d614, d56, d45, dPRC, d816,
  d1617, d717, d57 + d513, d1213, dSRC};
compareRClengths = Transpose[
  {RClengthsIO, RClengths, RClengths - RClengthsIO}] ;

```

(Debug) In[287]:=

formattedTableCompareLengths

(Debug) Out[287]=

Length	Length (mm)		
	T0900043-v11	Calculated	Difference
PRM to PR2	16603.7	16608.6	4.9
PR2 to PR3	16155.8	16162.6	6.8
PR3 to BS	19538.4	19537.4	-1.0
BS to CPy	4849.7	4847.8	-1.9
PRC	57656.0	57651.3	-4.7
SRM to SR2	15726.0	15460.1	-265.9
SR2 to SR3	15460.7	15740.0	279.3
SR3 to BS	19368.0	19365.8	-2.2
BS effective thickness	131.5	137.8	6.3
BS to CPx	4804.6	4829.6	25.0
SRC	56008.0	56008.5	0.5

■ L1

■ Notes

■ L1 Unique Parameters

- optic surface orientation determination
- BS position determination
- PR3 position determination
- PR2 position determination
- PRM position determination
- SR3 position determination
- SR2 position determination

- SRM position determination
- Schnupp Assymetry
- PRC Lengths
- SRC Lengths
- Summary

- Optic Parameters

(Debug) In[460]:=

```
opticLabel = {"PRM HR", "PR2 HR", "PR3 HR",  
             "BS HR", "BS ARs", "SRM HR", "SR2 HR",  
             "SR3 HR", "CPx", "ITMx", "CPy", "ITMy"};  
nOptics = Length[opticLabel];  
opticWedge =  
  {"NA", "NA", "NA", wedgeBS, "NA", "NA", "NA",  
   "NA", wedgeCPx, wedgeITMx, wedgeCPy, wedgeITMy};  
opticThick = {"NA", "NA", "NA", BSthick, "NA", "NA", "NA",  
             "NA", CPxThick, ITMxThick, CPyThick, ITMyThick};  
opticDiameter = {"NA", "NA", "NA", BSDiameter,  
                "NA", "NA", "NA", "NA", CPxDiameter,  
                ITMxDiameter, CPyDiameter, ITMyDiameter};
```

`(Debug) In[465]:=``formattedTableParameters``(Debug) Out[465]=`

Optic	wedge		Thickness	Diameter
	rad	deg		
PRM HR	NA	NA	NA	NA
PR2 HR	NA	NA	NA	NA
PR3 HR	NA	NA	NA	NA
BS HR	0.001222	0.070000	59.880000	369.980000
BS ARs	NA	NA	NA	NA
SRM HR	NA	NA	NA	NA
SR2 HR	NA	NA	NA	NA
SR3 HR	NA	NA	NA	NA
CPx	0.001274	0.073000	100.310000	339.940000
ITMx	0.001265	0.072500	200.270000	340.000000
CPy	0.001152	0.066000	100.320000	340.110000
ITMy	0.001292	0.074000	199.610000	339.920000

■ Results

`(Debug) In[466]:=`

```

opticLabel = {"PRM HR", "PR2 HR", "PR3 HR",
              "BS HR", "BS ARs", "SRM HR", "SR2 HR",
              "SR3 HR", "CPx", "ITMx", "CPy", "ITMy"};
nOptics = Length[opticLabel];
opticPositionG =
  {p15, p14, p6, p5, p7, p17, p16, p8, p11, p9, p3, p1};
opticPositionL = opticPositionG.Rlc;
opticNormalG =
  {n15, n14, n6, n5y, n13, n17, n16, n8, n11, n9, n3, n1};
opticNormalL = opticNormalG.Rlc;
opticYaw = {PRMyaw, PR2yaw, PR3yaw,
            BSyaw, 0, SRMyaw, SR2yaw, SR3yaw, 0, 0, 0, 0};

```

`(Debug) In[473]:=``formattedTablePositions``(Debug) Out[473]=`

Optic	Global Coordinates (mm)			Local Coordinates (mm)		
	Xg	Yg	Zg	Xl	Yl	Zl
PRM HR	-2018- 9.- 6	-628.0	-103.4	-2018- 9.- 6	-628.1	-96.7
PR2 HR	-3579- .2	-530.4	-93.7	-3579- .2	-530.5	-92.3
PR3 HR	-1974- 0.- 0	-176.4	-94.2	-1974- 0.- 0	-176.5	-87.9
BS HR	-202.5	-184.1	-82.8	-202.5	-184.2	-82.7
BS ARs	-183.9	-249.9	-82.9	-184.0	-249.9	-82.6
SRM HR	305.0	-1990- 8.- 6	-93.2	305.0	-1990- 8.- 7	-81.1
SR2 HR	-594.1	-4178- .1	-84.3	-594.1	-4178- .2	-81.6
SR3 HR	-175.3	-1961- 5.- 9	-94.1	-175.3	-1961- 6.- 0	-82.1
CPx	4792.9	-200.0	-80.0	4792.8	-200.0	-81.4
ITMx	5013.0	-200.0	-80.0	5013.0	-200.0	-81.4
CPy	-200.0	4763.7	-80.0	-200.0	4763.7	-82.9
ITMy	-200.0	4983.1	-80.0	-200.0	4983.1	-83.0

`(Debug) In[474]:=``formattedTableNormals``(Debug) Out[474]=`

Optic	Normal Unit Vector (global) (mm)			Normal Unit Vector (local) (mm)		
	Ug	Vg	Wg	Ul	Vl	Wl

PRM HR	0.999- 98- 3	0.005- 87- 6	0.000- 58- 5	0.999- 98- 3	0.005- 87- 6	0.000- 26- 9
PR2 HR	-0.99- 99- 68	0.008- 01- 2	-0.00- 03- 07	-0.99- 99- 68	0.008- 01- 1	-0.00- 00- 00
PR3 HR	0.999- 93- 8	-0.01- 11- 46	0.000- 30- 5	0.999- 93- 8	-0.01- 11- 46	0.000- 00- 0
BS HR	-0.70- 67- 84	0.707- 42- 9	0.000- 00- 0	-0.70- 67- 85	0.707- 42- 9	-0.00- 02- 12
BS ARs	0.705- 92- 0	-0.70- 82- 92	0.000- 00- 0	0.705- 92- 0	-0.70- 82- 92	0.000- 21- 3
SRM HR	-0.05- 70- 63	0.998- 37- 0	0.000- 56- 2	-0.05- 70- 63	0.998- 37- 1	-0.00- 00- 30
SR2 HR	0.042- 09- 5	-0.99- 91- 13	-0.00- 05- 97	0.042- 09- 5	-0.99- 91- 14	0.000- 00- 0
SR3 HR	-0.01- 37- 83	0.999- 90- 5	0.000- 60- 7	-0.01- 37- 83	0.999- 90- 5	0.000- 00- 0
CPx	0.999- 99- 9	0.000- 00- 0	-0.00- 12- 65	0.999- 99- 9	-0.00- 00- 01	-0.00- 15- 77
ITMx	1.000- 00- 0	0.000- 00- 0	0.000- 00- 0	1.000- 00- 0	0.000- 00- 0	-0.00- 03- 12
CPy	0.000- 00- 0	0.999- 99- 9	-0.00- 12- 92	-0.00- 00- 01	0.999- 99- 8	-0.00- 19- 03
ITMy	0.000- 00- 0	1.000- 00- 0	0.000- 00- 0	-0.00- 00- 00	1.000- 00- 0	-0.00- 06- 11


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(Debug) In[475]:=
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formattedTableAngles
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```
(Debug) Out[475]=
```

Optic	Yaw			
	rad	deg	min	sec
PRM HR	-0.005876	0.	-20.	-12.
PR2 HR	0.008011	0.	27.	32.
PR3 HR	-0.011146	0.	-38.	-19.
BS HR	-0.784942	-44.	-58.	-26.
BS ARs	0.000000	0.	0.	0.
SRM HR	-0.057094	-3.	-16.	-17.
SR2 HR	-0.042108	-2.	-24.	-45.
SR3 HR	0.013783	0.	47.	23.
CPx	0.000000	0.	0.	0.
ITMx	0.000000	0.	0.	0.
CPy	0.000000	0.	0.	0.
ITMy	0.000000	0.	0.	0.

■ Zemax results

Zemax results are from D0902216 - v8

The wedge angle magnitudes (but not orientations/signs) reported in the Zemax optical layout, D0902216-v8 match the serial numbers and wedge angle values given above.

```
(Debug) In[476]:=
```

```

opticLabelZemax = {"PRM HR", "PR2 HR",
    "PR3 HR", "BS HR", "BS ARs", "SRM HR", "SR2 HR",
    "SR3 HR", "ITMx", "ITMy", "ETMx", "ETMy"};
nOpticsZemax = Length[opticLabelZemax];
opticPosGZemax = {{-20190.0, -628.0, -102.8},
    {-3579.6, -530.4, -93.3}, {-19740.5, -176.3, -93.9},
    {-202.5, -184.0, -82.8}, {-183.9, -250.0, -82.9},
    {305.0, -19908.6, -93.2}, {-594.1, -4178.1, -84.4},
    {-175.2, -19615.9, -94.1}, {5013.0, -200.0, -80.0},
    {-200.0, 4983.1, -80.0}, {3999498.0, -200.0, -80.0},
    {-200.0, 3999468.1, -80.0}};

```

(Debug) In[479]:=

```
compareOpticLabel = opticLabelZemax[[1 ;; 10]];
nCompareOptics = 10;
comparePositionG = Drop[opticPositionG, {9, 11, 2}] -
  opticPosGZemax[[1 ;; 10]];
```

(Debug) In[482]:=

```
formattedTableComparePositions
```

(Debug) Out[482]=

Optic	Global Coordinate Difference (mm)		
	D _{Xg}	D _{Yg}	D _{Zg}
PRM HR	0.4	-0.0	-0.6
PR2 HR	0.4	-0.0	-0.4
PR3 HR	0.5	-0.1	-0.3
BS HR	-0.0	-0.1	-0.0
BS ARs	-0.0	0.1	0.0
SRM HR	0.0	0.0	0.0
SR2 HR	0.0	0.0	0.1
SR3 HR	-0.1	0.0	-0.0
ITM _x	0.0	0.0	0.0
ITM _y	0.0	0.0	0.0

■ IO results

IO Layout results for PRM, PR2 and PR3 are from E1100492-v11, E1100493-v9

```
opticLabelIO = {"PRM HR", "PR2 HR", "PR3 HR"};
```

```
nOpticsIO = Length[opticLabelIO];
```

```
opticPosGIO = {{-20189.6, -628, -104.1}, {-3579.2, -530.4, -94.1}, {-19740, -177.4, -94.5}};
```

IO Layout results for PRM, PR2, PR3, SRM, SR2 and SR3 are from E1200274-v3 for L1 in global coordinates

(Debug) In[483]:=

```

opticLabelIO =
  {"PRM HR", "PR2 HR", "PR3 HR", "BS HR", "BS ARs",
   "SRM", "SR2", "SR3", "CPx", "ITMx", "CPy", "ITMy"};
nOpticsIO = Length[opticLabelIO];
opticPosGIO =
  {{-20189.6, -628, -104.1}, {-3579.2, -530.4, -94.2},
   {-19740.0, -177.4, -94.4}, {-201.9, -183.9, -82.9},
   {-183.3, -249.8, -83.2}, {305.2, -19909.0, -94.3},
   {-594.3, -4178.1, -84.8}, {-175.5, -19615.9, -94.5},
   {4793.0, -200.0, -80.0}, {5013.0, -200.0, -80.0},
   {-200.0, 4763.1, -80.2}, {-200.0, 4983.1, -80.0}};

```

(Debug) In[486]:=

```

compareOpticLabel = opticLabelIO;
nCompareOptics = Length[compareOpticLabel];
comparePositionG = opticPositionG - opticPosGIO;

```

(Debug) In[489]:=

```

formattedTableComparePositions

```

(Debug) Out[489]=

Optic	Global Coordinate Difference (mm)		
	DXg	DYg	DZg
PRM HR	-0.0	-0.0	0.7
PR2 HR	-0.0	-0.0	0.5
PR3 HR	0.0	1.0	0.2
BS HR	-0.6	-0.2	0.1
BS ARs	-0.6	-0.1	0.3
SRM	-0.2	0.4	1.1
SR2	0.2	0.0	0.5
SR3	0.2	0.0	0.4
CPx	-0.1	0.0	-0.0
ITMx	0.0	0.0	0.0
CPy	0.0	0.6	0.2
ITMy	0.0	0.0	0.0

■ RC Length Results

(Debug) In[490]:=

```

RClengthsLabel =
  {"PRM to PR2", "PR2 to PR3", "PR3 to BS", "BS to CPy",
   "PRC", "SRM to SR2", "SR2 to SR3", "SR3 to BS",
   "BS effective thickness", "BS to CPx", "SRC"};
nRClengths = Length[RClengthsLabel];
RClengthsIO = {dPRMtoPR2, dPR2toPR3,
  dPR3toBS, dBStoCPy, dPRCIO, dSRMtoSR2,
  dSR2toSR3, dSR3toBS, dBSe, dBStoCPx, dSRCIO};
RClengths = {d1415, d614, d56, d45, dPRC, d816,
  d1617, d717, d57 + d513, d1213, dSRC};
compareRClengths = Transpose[
  {RClengthsIO, RClengths, RClengths - RClengthsIO}];

```

(Debug) In[495]:=

```
formattedTableCompareLengths
```

(Debug) Out[495]=

Length	Length (mm)		
	T0900043-v11	Calculated	Difference
PRM to PR2	16610.7	16610.7	-0.0
PR2 to PR3	16164.7	16164.7	-0.0
PR3 to BS	19538.1	19537.5	-0.6
BS to CPy	4862.0	4847.7	-14.3
PRC	57656.0	57655.7	-0.3
SRM to SR2	15758.6	15443.5	-315.1
SR2 to SR3	15443.5	15756.2	312.7
SR3 to BS	19366.1	19366.0	-0.1
BS effective thickness	131.5	136.7	5.2
BS to CPx	4804.6	4829.5	24.9
SRC	56008.0	56007.6	-0.4

■ SRC alignment per IAS procedure E1100784-v6

Check that positions set per the Initial Alignment Subsystem (IAS) procedure are consistent with the positions given above

For SR2, monument “TS-2” is used for positioning

(Debug) In[496]:=

```
pTS2 = {367.43, -27 000.0, -81.60};
pitch = 0;
yaw = RAD[87, 35, 15] // N;
distanceAlignSR2HR = 22 842.04;
uAlignSR2HR =
  RotationTransform[-yaw, {0, 0, 1}][{-1, 0, 0}]
```

(Debug) Out[500]=

```
{-0.0420936, 0.999114, 0.}
```

(Debug) In[501]:=

```
pSR2IAS = pTS2 + distanceAlignSR2HR uAlignSR2HR
opticPositionL[[7]]
pSR2IAS - opticPositionL[[7]]
```

(Debug) Out[501]=

```
{-594.074, -4178.21, -81.6}
```

(Debug) Out[502]=

```
{-594.125, -4178.15, -81.5948}
```

(Debug) Out[503]=

```
{0.0510217, -0.054854, -0.00521101}
```

Check that positions set per the Initial Alignment Subsystem (IAS) procedure are consistent with the positions given above

For SR3, monument “TS-1” is used

(Debug) In[504]:=

```
pTS1 = {-73.43, -27 000.0, -8.987};
pitch = Pi / 2 - RAD[90, 34, 30];
yaw = RAD[89, 12, 37] // N;
distanceAlignSR3HR = 7283.2;
uAlignSR3HR = RotationTransform[pitch, {1, 0, 0}][
  RotationTransform[-yaw, {0, 0, 1}][{-1, 0, 0}]]
```

(Debug) Out[508]=

```
{-0.0137828, 0.999855, -0.0100345}
```

```
(Debug) In[509]:=  
  pSR3IAS = pTS1 + distanceAlignSR3HR uAlignSR3HR  
  opticPositionL[[8]]  
  pSR3IAS - opticPositionL[[8]]
```

```
(Debug) Out[509]=  
  {-173.813, -19717.9, -82.0704}
```

```
(Debug) Out[510]=  
  {-175.333, -19616., -82.0603}
```

```
(Debug) Out[511]=  
  {1.52048, -101.905, -0.0101233}
```

The distance used in the IAS procedure already has the thickness of the SR3 optic taken into account. This is OK is the remaining offset taken into account was to the AR surface. HOWEVER, the procedure says to account for an offset to the HR face!

